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THREE METHODS FOR DISTRIBUTING METHYL BROMIDE IN FARM-TYPE BINS OF WHEAT AND CORN

Marketing Research Report No. 929

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Howard D. Nelson, formerly Assistant Station Leader at Mid-West Grain Insects Investigations, Manhattan, Kans., did the statistical work of reducing the data obtained in the replicated tests to single comparable figures. Mr. Nelson is now Investigations Leader of the Dried Fruit and Tree Nut Insects Investigations, Fresno, Calif. R. L. Ernst, Mid-West Grain Insects Investigations, assisted in the tests.

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2091

THREE METHODS FOR DISTRIBUTING METHYL BROMIDE IN FARM-TYPE BINS OF WHEAT AND CORN

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SUMMARY

Methyl bromide fumigations were conducted in wheat and corn stored in 3,250-bushel metal bins and small, wooden buildings, each equipped with a horizontal floor duct.

In exploratory fumigations, several methods of applying and distributing the methyl bromide were tried. In the metal bins, the closed-recirculation method and the single-pass method seemed more satisfactory than the others tested. These two methods, along with the gravity-penetration method as a standard for comparison, were replicated three times in both wheat and corn to determine which method produced the most rapid and uniform distribution of the fumigant.

In the closed-recirculation method, the methyl bromide was released into the overhead space above the grain surface, and pulled down through the grain mass by a fan that pushed it through a flexible return duct back to the overhead space. In the single-pass method, the methyl bromide was released into the overhead space and pulled down through the grain mass by a fan, which was stopped as soon as the fumigant reached the aeration duct. In the gravity-penetration method, the methyl bromide was released into the overhead space and allowed to penetrate into the grain mass by the force of gravity.

Only the closed-recirculation method was replicated in the wooden bins. A plastic tarpaulin covering the entire building was required to maintain adequate gas concentrations in the loosely constructed wooden bins.

Data obtained in the replicated tests were reduced to single comparable figures by means of the homogeneity of variance method of statistical analysis.

Results of the statistical analysis showed that distribution of gas was more uniform by the closed-recirculation method, using horizontal floor ducts, than by the other methods tested.

INTRODUCTION

Since 1965, increasing quantities of grain under Commodity Credit Corporation (CCC) loan are being held in farm-type bins. More effective and more economical fumigation procedures are needed to reduce storage and treatment costs in these low-capacity storage facilities. The value of forced-distribution method for applying fumigants to bulk grain in large storage structures has been demonstrated.[2] To apply the same method of fumigation to grain stored in farm-type bins, more background information was needed on which to base sound recommendations.

This report presents the results of fumigation studies that were conducted to determine which application method would consistently and uniformly distribute fumigants in small, farm-type storage bins. In addition, several simple types of aeration ducts were tested in the single-pass and closed-recirculation methods of fumigation so that the different patterns of distribution could be evaluated.

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[2] Storey, C. L. COMPARATIVE STUDY OF METHODS OF DISTRIBUTING METHYL BROMIDE IN FLAT STORAGES OF WHEAT: GRAVITY-PENETRATION, SINGLE-PASS, AND CLOSED-RECIRCULATION. U.S. Dept. Agr., Market. Res. Rpt. 794, 16 pp. 1967.

EXPLORATION OF TEST METHODS

Procedure

A series of methyl bromide fumigations was conducted on corn and wheat stored in 3,250-bushel bins located on the Commodity Credit Corporation (CCC) binsite near Herkimer, Kans. The bins were of two types—metal circular bins (fig. 1) and small, 12- by 24- by 10-foot wooden buildings (fig. 2).

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Figure 1.—Metal bin.

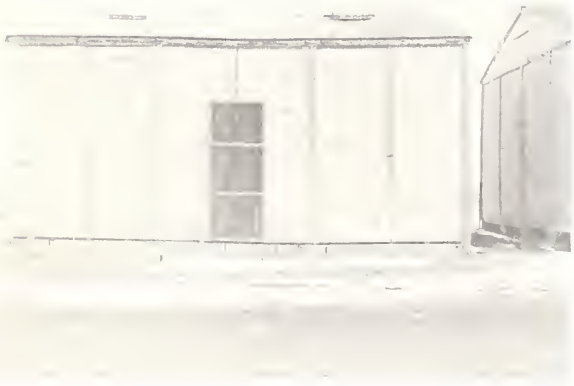

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Figure 2.—Wooden bin.

After a permanent duct system was installed across each bin floor, the bins were filled with grain. Three types of duct systems were used. The first type was 14 feet of 6-inch-diameter, perforated metal well casing, attached at one end to a 3-foot section of unperforated casing which extended through the bin wall (fig. 3).

PN-1918

FIGURE 3.—Six-inch well casing duct that was placed across the floor of the bins.

The second type was a V-shaped, inverted trough made from two boards, 1 by 10 inches by 14 feet and 1 by 8 inches by 14 feet (fig. 4). The third type was a 6-inch-square, inverted trough made from two boards 1 by 6 inches by 14 feet and one board 1 by 8 inches by 14 feet (fig. 5). Three-foot sections of unperforated well casing that extended to the outside were also attached at one end of each of the two types of wooden ducts. Both types of wooden ducts were placed on short sections of 2 by 4's to raise them off the floor so that air could be pulled into the ducts along both edges. Wire screen was tacked to the bottom of the wooden ducts to prevent grain from being pulled into the system.

The tops and eaves of the metal bins were sealed with 2- and 3-inch-wide strips of masking tape. The wooden bins were covered with polyethylene sheeting 48 feet wide, 60 feet long, and 0.004 inch thick.

Both the metal and wooden bins used in this test series contained about 3,250 bushels of wheat or corn. Tests were conducted during May, June, July, and August. Temperatures in the center of the grain mass ranged from 54° F. in May to 75° in August. Temperatures in the

PN-1919

FIGURE 4.—Wooden, inverted trough duct that was placed across the floor of the bins.

PN-1920

FIGURE 5.—Wooden, square duct that was placed across the floor of the bins.

overhead space above the grain surface often exceeded 100° during July and August.

Various methods of applying and distributing the methyl bromide were tried. In some tests the methyl bromide was released through a copper tube directly into the duct system and was pushed up through the grain mass by a fan until the fumigant reached the surface of the grain. In part of the tests, the fan was stopped at this point. In other tests, a return duct was attached to the top of the bins to permit recirculation of the fumigant. In similar tests, the fan was reversed and the methyl bromide was drawn down through the grain mass. In further tests, the methyl bromide was released into the overhead space and allowed to penetrate down through the grain mass without the use of fans.

In the exploratory tests, gas sampling probes were used in various arrangements to determine which probe placement pattern most accurately reflected the distribution of the methyl bromide in both types of bins. Gas sample readings in the metal bins were made with the thermal conductivity instrument from five tiers of gas sample probes at periods of 30 minutes and 2, 4, 8, and 24 hours after the methyl bromide was applied. Each tier was composed of sampling points located at the surface and at the 5-, 10-, and 15-foot or bottom levels. Four sampling tiers were located in the outer edge of the grain mass, and the fifth tier was placed in the center of the bin. Nine sampling tiers were used in the wooden building; eight tiers of sample probes were located in the outer edge of the grain mass; and the ninth tier was placed in the center of the bin. Each tier was composed of sampling points located at the surface and at the 2½-, 5-, and 10-foot or bottom levels.

The methyl bromide was metered into the bins through an applicator designed to accurately measure 3-pound increments of the liquid fumigant directly from the cylinder (fig. 6). The application nozzles atomized the liquid methyl bromide and converted it to a gas. A dosage of 2 pounds per 1,000 cubic feet was used in most of the tests.

A 6-inch fan, powered by a 5-hp. gasoline engine, circulated the fumigant (fig. 7). The

PN–1921

FIGURE 6.—Three-pound methyl bromide applicator, attached to a gas cylinder.

airflow produced by the fan varied with the kind and condition of the grain being fumigated. In the wheat fumigations, the airflow ranged from 0.09 c.f.m. per bushel to 0.12 c.f.m. per bushel. In the corn fumigations, the airflow range was from 0.14 c.f.m. per bushel to 0.18 c.f.m. per bushel.

Results

The gas distribution pattern, range of gas concentration, and total amount of free interstitial gas obtained by each method of fumigation were compared. Results of the exploratory tests were as follows:

1. Regardless of the method used to distribute the fumigant in the metal bins, the eaves and access doors had to be sealed with masking tape. This was necessary to retain adequate gas concentrations at the surface and in the overhead space in the bins and to prevent drifting of the vapors by the wind outside.

2. The maintenance of the minimum gas concentrations required a complete gastight cover over the loosely constructed wooden bins.

3. Results in the gravity-penetration fumigations were inconsistent. In some tests, the methyl bromide penetrated very rapidly to the bottom of the bin and then "bounced" off in different directions. In other tests, the gas remained highly concentrated in the overhead space and on the surface of the grain, and only traces of the gas reached the bottom of the bin.

4. In fumigations by the recirculation method, the range between the highest and lowest gas concentrations recorded at various sample locations was fairly small, indicating a uniform distribution. However, in this method the average concentration of interstitial gas recovered at all levels in the grain was much less than in the single-pass or gravity-penetration methods. The longer time of fan operation required in the recirculation method may tend to increase gas leakage from the bin and grain sorption of methyl bromide.

5. In single-pass fumigations of corn, similar distribution patterns were obtained for the different directions of air movement. However, when air was pushed upward through the grain, the cooler grain temperatures in the bottom of the bin caused some difficulty in volatilizing

PN–1922

FIGURE 7.—Six-inch fan used to distribute the methyl bromide.

the methyl bromide rapidly after the gas was released into the duct. The prolonged fan operation, required to distribute the high concentrations of methyl bromide in the bottom of the bin, resulted in considerable loss of gas through the outlet in the top of the bin. When the direction of air movement was reversed and the methyl bromide was released into the incoming airstream in the top of the bin, the gas was volatilized rapidly, and the fan operation was limited to the time required for a single air change.

TESTS OF GAS DISTRIBUTION

Procedure

The closed-recirculation method and the single-pass method used to distribute methyl bromide in the metal bins appeared, in the exploratory tests, to be more satisfactory than the other methods tested. The gravity-penetration method was chosen as a standard for comparison. In the metal bins, these three methods were replicated three times in both wheat and corn to determine which method produced the most rapid and uniform distribution of the fumigant. In the wooden bins, only the closed-recirculation method was repeated.

Single-pass method in metal bins.—The fan was operated for the time calculated to produce one complete air change. The time was 6 minutes in the wheat fumigations and 4 minutes in the corn fumigations. The introduction of gas into the overhead space above the grain surface was prorated over this period. No return duct was used. The eaves and doors of the bins were sealed with masking tape.

Gravity-penetration method in metal bins.—Gravity was the distributing force in this fumigation method. The total dosage of 9 pounds of methyl bromide was released as rapidly as possible in the overhead space and allowed to distribute itself throughout the grain mass. These bins were also sealed with masking tape.

Closed-recirculation method in metal bins.—A 6-inch-diameter flexible return duct was attached to the top of the bin, and the intake of the fan was connected to the permanent duct in the bottom of the bin. In an effort to spread the fumigant evenly over the surface of the grain before pulling it into the grain mass, a special adapter connected the 6-inch, flexible return duct to the fill hole in the top of the metal bins (fig. 8). A ⅛-inch pipe with a nozzle released the fumigant inside the adapter directly into the airstream of the return duct. The 9 pounds of methyl bromide required for a dosage rate of 2 pounds per 1,000 cubic feet was applied in 3-pound lots, released 5 minutes apart in the wheat fumigations and 4 minutes apart in the corn fumigations. The fan was operated for about 15 minutes in the wheat fumigations and 12 minutes in the corn fumigations. The eaves and access doors in the roof of the bins were sealed with masking tape before each fumigation. Combination gas sample and test insect probe points containing adult confused flour beetles, adult rice weevils, and immature rice weevils were used to test the effectiveness of the fumigation.

Closed-recirculation method in wooden bins.—In the exploratory fumigations of wooden bins with methyl bromide, only one method gave satisfactory results. Consequently, only this method was used in the replication of fumigations in the wooden bins. The gas was released into the overhead space and recirculated under a complete plastic tarpaulin cover. The edges of the tarpaulin, the return duct,

PN-1923

FIGURE 8.—View of the fill hole adapter constructed to accommodate the 6-inch flexible return duct and the applicator hose.

the applicator hose, and the gas sample lines were buried underground to obtain an effective seal.

Results

The closed-recirculation method of fumigation produced a more uniform distribution of the methyl bromide in both wheat and corn stored in 3,250-bushel bins, both metal and wooden, than the single-pass and gravity-penetration methods.

In all methods used to distribute the fumigant, similar distribution patterns were recorded by the end of the 8-hour sampling period.

In single-pass fumigations for both wheat and corn, the average concentrations of interstitial gas recorded in the five sampling periods were greater than the average gas concentrations in recirculation and gravity-penetration fumigations.

In gravity-penetration fumigations of wheat, considerable gas was lost, on particularly windy days, even though the eaves and access doors of the bins were sealed with masking tape. Penetration of the methyl bromide into the wheat was slower and resulted in excess gas in the overhead space. Also, some gas leaked out through crevices in the bin roof.

All three types of ducts used to distribute the fumigant produced similar distribution patterns for the single-pass and closed-recirculation fumigations.

The closed-recirculation fumigations killed 100 percent of the adult test insects when the application rate was 2 pounds of methyl bromide per 1,000 cubic feet in corn and 2½ pounds of methyl bromide per 1,000 cubic feet in wheat. Percent of mortality could not be estimated for immature rice weevils because of poor emergence of the control weevils.

Initial distribution of methyl bromide applied by the recirculation method in the wooden bins was more uniform in corn than in wheat.

Statistical Analysis of Results

The homogeneity of variance method of statistical analysis, was used to reduce the great bulk of data obtained in the replicated tests to single comparable figures. Table 1 gives a summary of the estimates of variance for gas concentration data obtained in the replicated tests in circular metal bins. A comparison of the average estimate of variance in the wheat and corn fumigations shows that gas distribution during the 30-minute to 8-hour sampling periods was significantly more uniform in the closed-recirculation fumigations than that obtained in the single-pass or gravity-penetration fumigations. Differences between the three methods were not significant at the 24-hour sampling period.

Table 2 gives a summary of the estimate of variance for gas concentration data obtained in the replicated closed-recirculation fumigations in rectangular wooden bins. A comparison of the average estimate of variance obtained in these fumigations shows that distribution was significantly more uniform in corn at the 30-minute and 2-hour sampling periods than it was in wheat. Thereafter, differences between the two commodities were not statistically significant.

DISCUSSION

Data obtained in this study demonstrate the greater efficiency of the closed-recirculation method, using horizontal floor ducts, for obtaining uniform distribution of the fumigant. However, justification for the additional cost of recirculation equipment would depend in part on whether the increased efficiency would permit the use of substantially lower rates of application, thereby making treatment of a farm-type bins more economical.

Some farm-type bins are now being constructed without the open gap between the sidewall and the roof eaves. This would eliminate much of the sealing required to maintain adequate fumigant concentrations at the grain surface and in the overhead space above the grain. With the addition of an inexpensive wooden or well casing floor duct and a portable or permanent return duct, this type of bin could readily be fumigated by the closed-recirculation method.

TABLE 1.—*Estimates of variance for gas concentration data obtained by fumigating wheat and shelled corn stored in circular metal 3,250-bushel bins with 2 pounds of methyl bromide per 1,000 cubic feet* [1]

Test No.	Type of duct	Estimate of variance of gas concentration readings at the end of each sampling period				
		30 min.	2 hours	4 hours	8 hours	24 hours
			WHEAT			
			Gravity-penetration			
26	None	254.40	79.95	56.68	30.75	3.62
38	do	371.28	14.00	10.88	4.42	1.43
42	do	624.02	26.65	3.68	5.60	2.33
			Single-pass			
35	Triangular	308.12	125.73	62.28	17.08	7.38
43	Square	107.78	33.43	13.17	14.08	5.80
44	Triangular	63.17	29.32	15.70	15.92	3.35
			Closed-recirculation			
1	Square	79.32	24.05	10.68	3.37	.73
33	Triangular	31.10	11.73	6.95	1.77	2.25
39	do	21.35	7.35	4.07	4.10	2.00
46	do	18.47	8.23	6.30	4.80	6.12
49	Circular	22.28	8.40	5.57	2.18	3.15
50	Triangular	14.67	4.82	6.12	4.60	1.65
			SHELLED CORN			
			Gravity-penetration			
25	None	1940.52	515.32	204.52	25.98	2.55
29	do	849.22	39.42	19.43	7.92	1.38
37	do	174.73	28.48	13.97	9.45	2.12
			Single-pass			
28	Square	80.90	30.83	17.17	5.55	.87
31	do	780.62	92.58	23.30	7.90	2.33
32	do	334.53	53.00	25.28	8.38	3.10
			Closed-recirculation			
2	Triangular	104.33	28.42	7.37	6.48	2.52
24	Square	11.53	4.72	6.77	4.42	1.52
36	do	12.63	6.23	6.35	3.33	1.97
40	do	22.57	2.95	5.20	5.97	1.48
48	Triangular	31.89	6.80	11.85	5.71	.87

[1] The homogeneity of variance method was used in summarizing the data. To compare any one estimate of variance with any other estimate of variance, divide the greater by the smaller. If the quotient equals or exceeds 2.86, the divisor or smaller variance indicates a significantly more uniform distribution of the fumigant under that particular circumstance.

TABLE 2.—*Estimates of variance for gas concentration data obtained by the closed-recirculation method of fumigating wheat and shelled corn stored in rectangular wooden buildings*[1] *with 2 pounds of methyl bromide per 1,000 cubic feet*[2]

Test No.	Type of duct	Estimate of variance of gas concentration readings at end of each sampling period				
		30 min.	2 hours	4 hours	8 hours	24 hours
WHEAT						
27	Square	158.30	11.13	4.21	2.90	0.56
30	do	14.31	6.06	1.55	1.06	.46
34	do	160.19	17.97	3.37	1.11	.67
SHELLED CORN						
41	Square	33.58	3.66	1.39	.85	1.00
45	do	11.43	1.64	1.13	.82	.81
47	Triangular	23.19	8.07	2.94	1.05	.25

[1] The buildings were covered with gastight plastic tarpaulins. The fan was operated for 12 minutes.

[2] The homogeneity of variance method was used in summarizing the data. To compare any one estimate of variance with any other estimate of variance, divide the greater by the smaller. If the quotient equals or exceeds 2.16, the divisor or smaller variance indicates a significantly more uniform distribution of the fumigant under that particular circumstance.

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